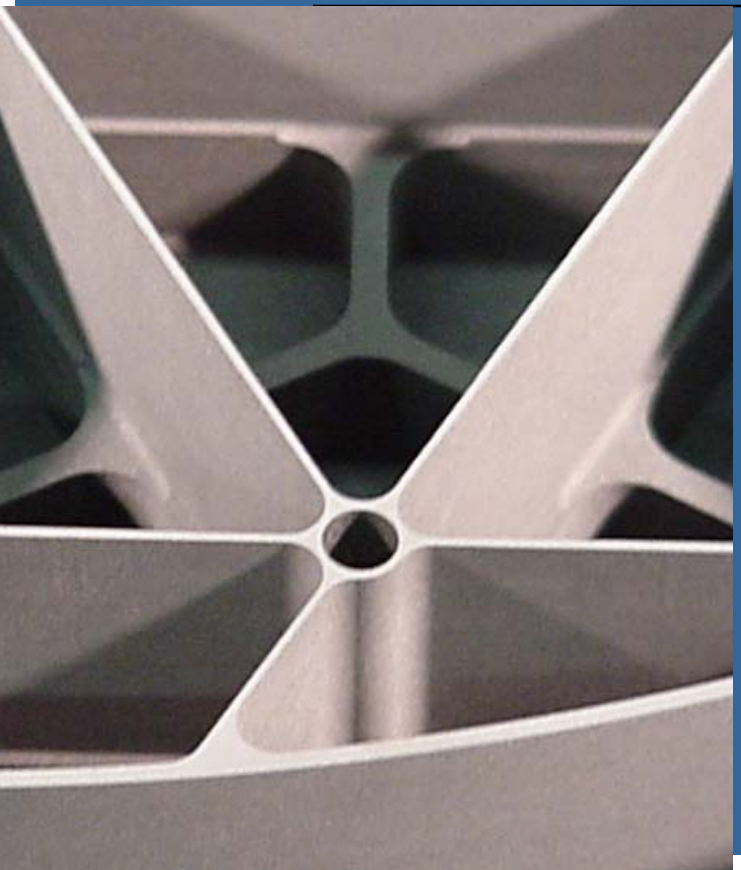
Design and Fabrication of SuperSiC® ¼ Meter Mirror for Cryogenic Testing



A solution for
Precision Optics

Donald J. Bray
Poco Graphite, Inc.
John Casstevens
Dallas Optical Systems, Inc.

Overview of Project

- Poco's SuperSiC appears to have attributes that make it a particularly attractive material for aerospace optics applications
- MSFC (Phil Stahl) has a program to evaluate the Poco SuperSiC technology for cryo-optics applications
- A mirror has been fabricated and will be tested in the near future
- This presentation will discuss the fabrication and polishing

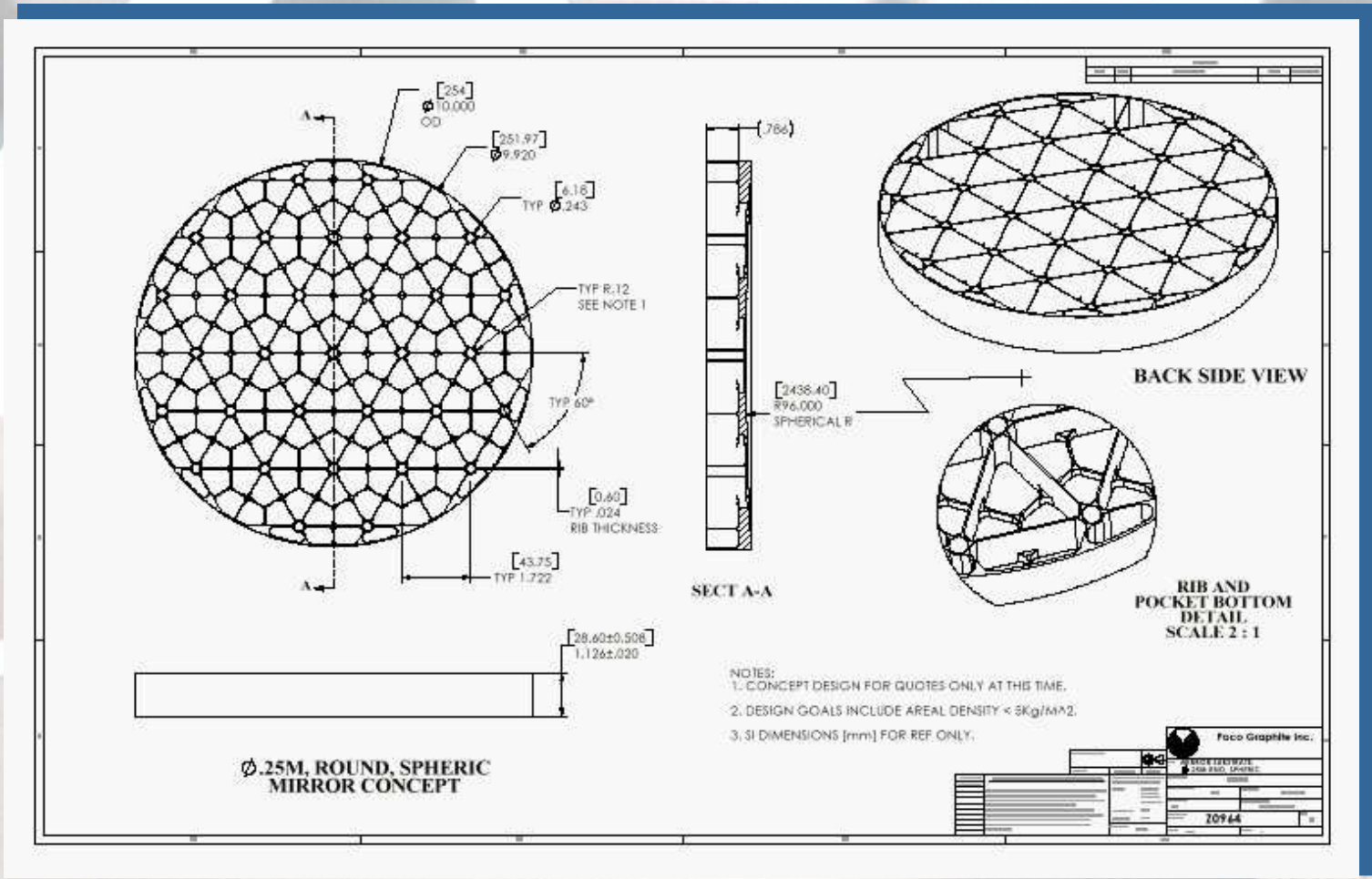
Summary of Cryo-optics Project

- POCO SuperSiC (silicon carbide) mirror fabricated with the following characteristics:
  - Quarter Meter Spherical Mirror.
  - Circular periphery 0.25 meter diameter (9.75 inches)
  - 50-100 mm(1-2 inch) depth
  - With a radius of curvature of 3 meters.
  - This mirror will have a lightweighting structure similar to that used on the 0.5 meter flat (previous program at Poco ~15 kg/m^2).
  - Polished by Dallas Optical Systems, Inc.

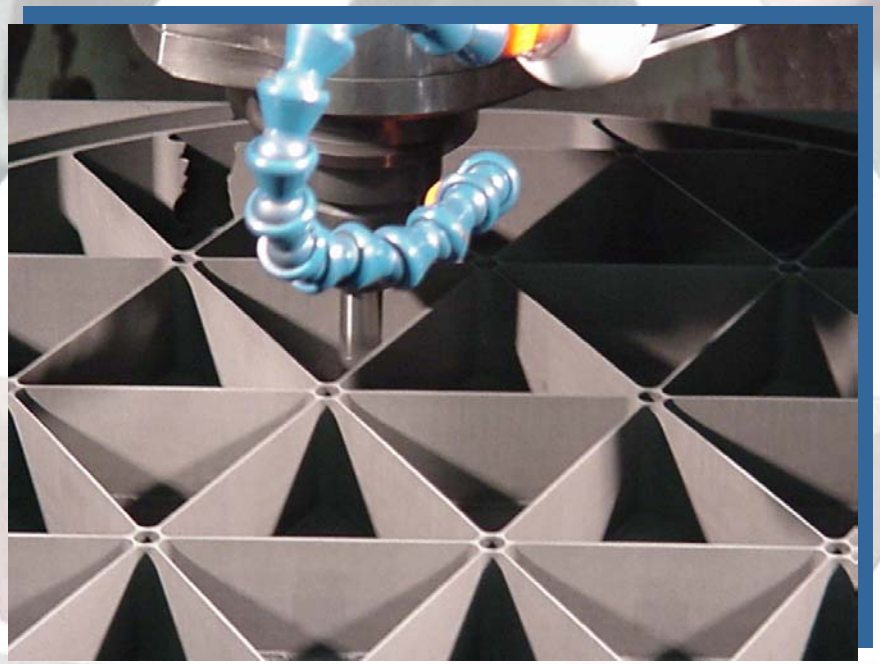
Mirror Design

- SuperSiC fabrication process allows very thin webs and complex designs to maximize stiffness and address attachment
  - Face plate = 2mm
  - Rib structure = 1mm
  - Areal density = 16 kg/m^2
- Two Designs
  - Light-weight
  - Robust
- Mirror designed for high manufacturability

Drawing for 0.25 meter spherical mirror



Graphite Machining

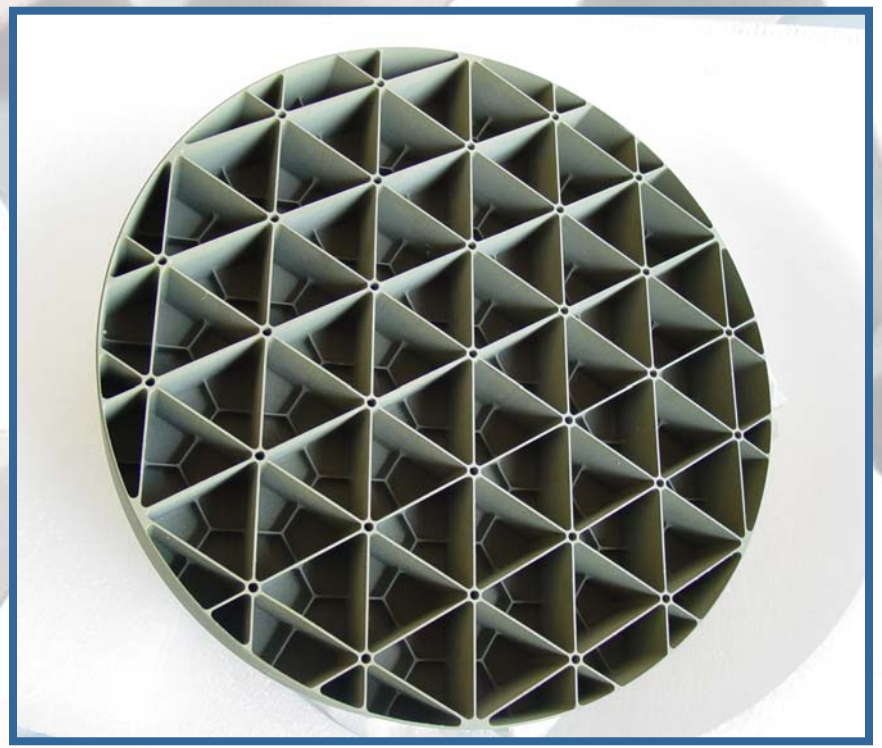


Machining Open Back Graphite Substrate
0.5 meter diameter, flat.

- Advantages
  - Machinability equal to or better than aluminum
  - Very tight tolerances
  - Graphite has good strength
  - Reproducibility, very uniform microstructure

Conversion to SiC

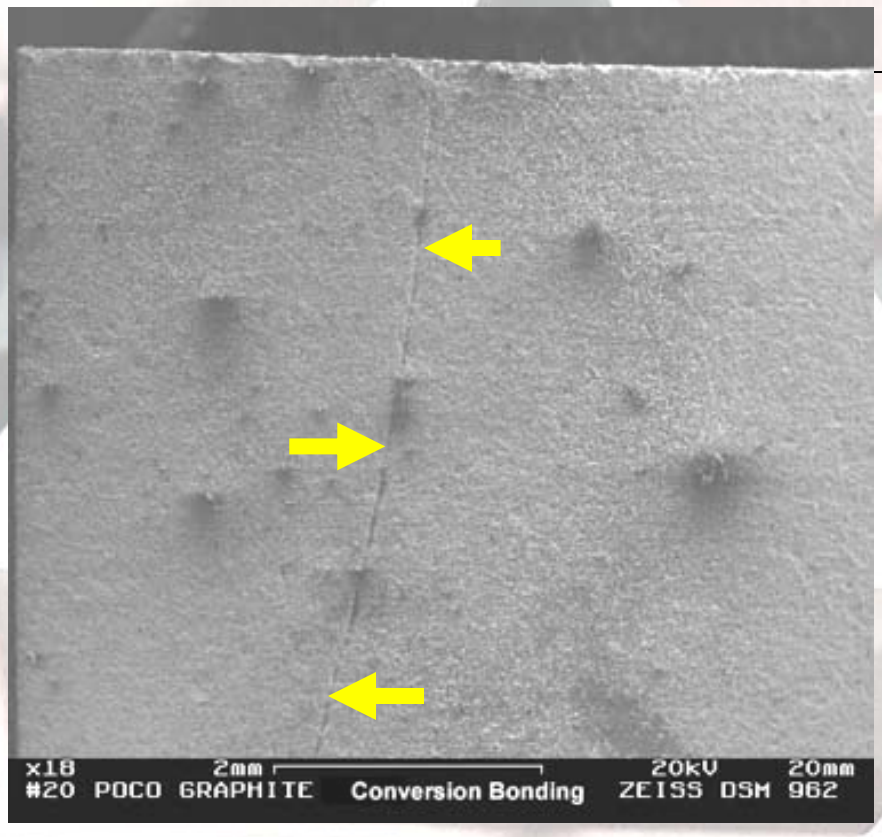
- Back Surface of 0.25 meter SuperSiC®
  - One step process, graphite to SiC
  - High accuracy, net shape



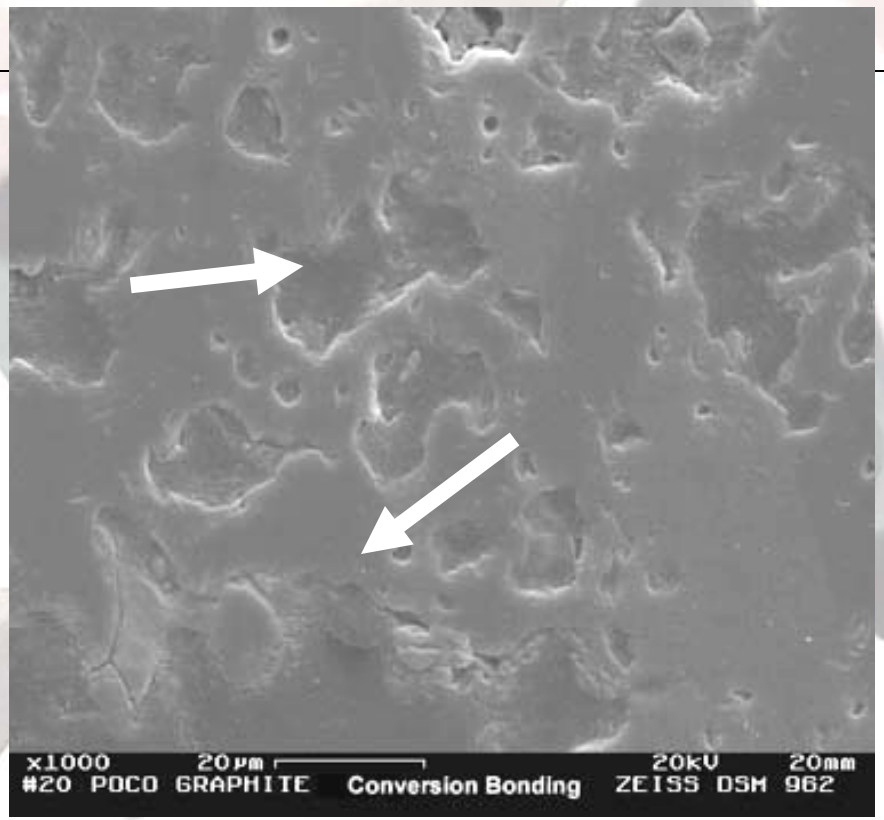
Conversion Bonding

- Poco has developed a “conversion bonding” process
- The SiC conversion bond has been demonstrated qualitatively to be as strong or stronger than a single (monolithic) SiC converted piece.
- This process allows
  - Closed back mirror construction
  - Mirror mounting
  - Allows scaling to large, monolithic mirrors and optics structures
  - CONCLUSION
- There appears to be no observable structural or morphological differences between the mated pieces and the seam. Higher magnification images show grain structure formation across the area of the seam. The mating pieces appear to be one unit/piece after conversion bonding.

Conversion Bonding



Arrows show the chamfered seam in the face view. The disk is on the left and the mating piece is on the right.

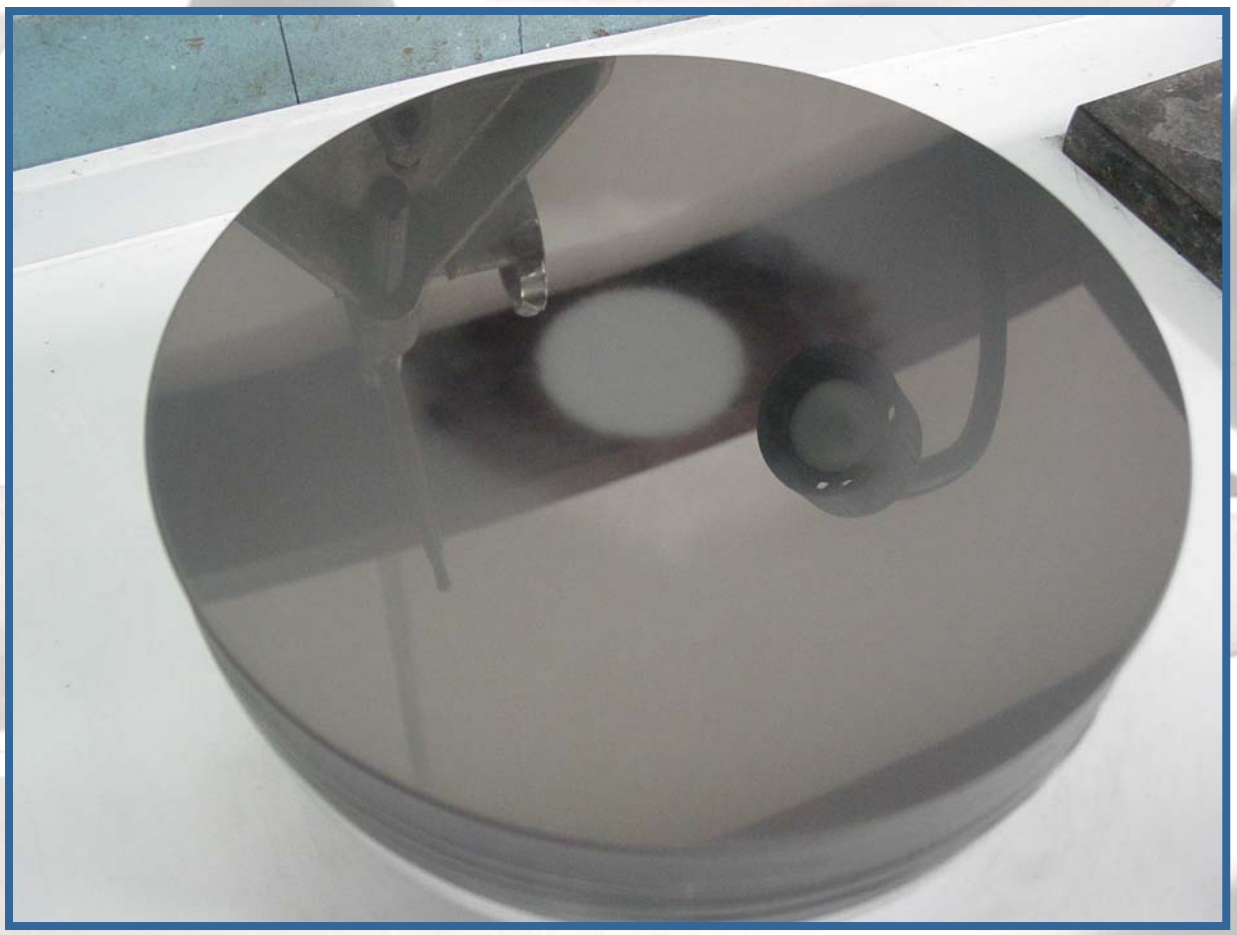


White arrow shows grain structure crossing the area of the seam.

SiC Mirror Sphere Polishing Set Up

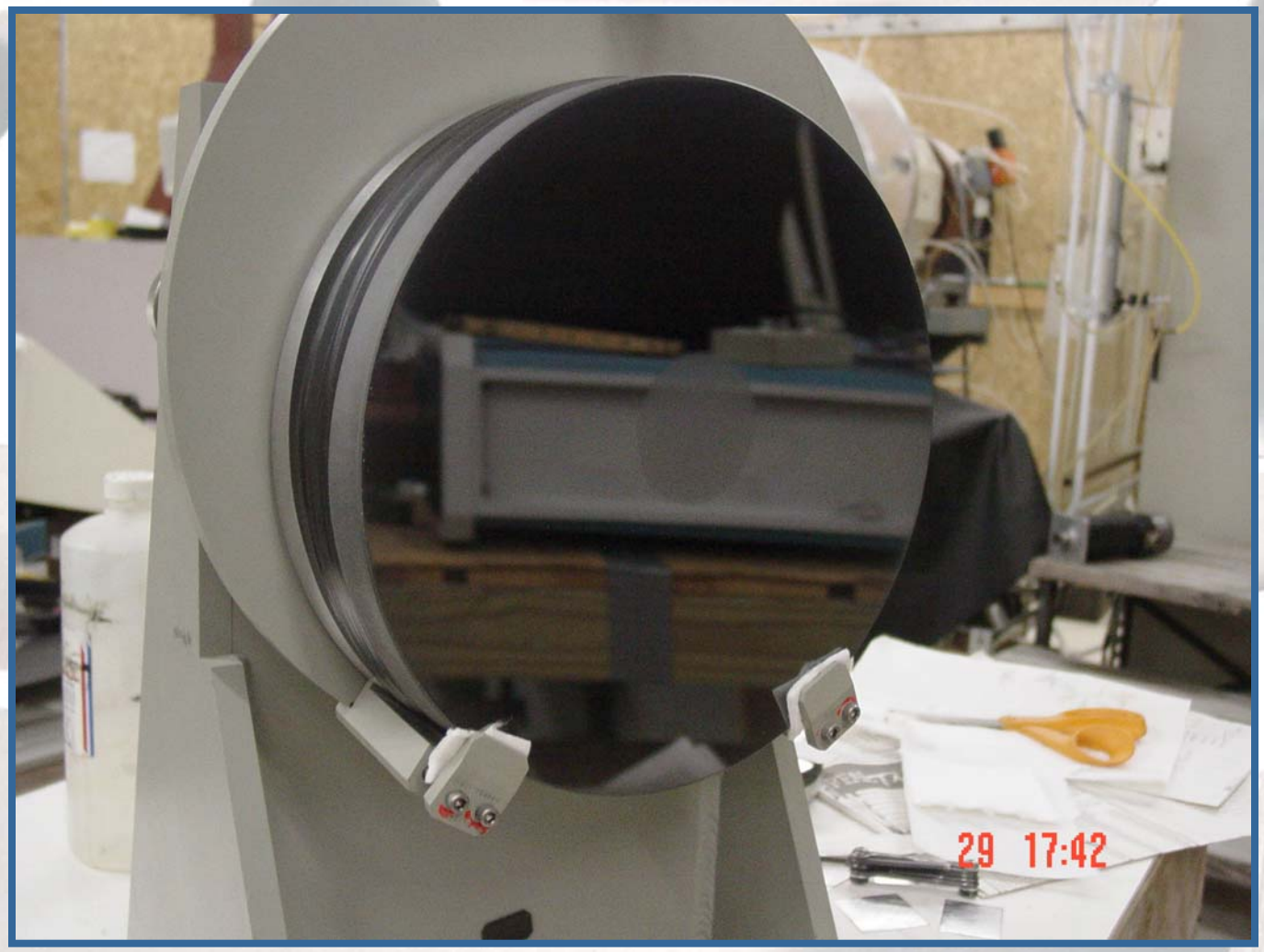
Cushion Showing Imprint of Mirror Ribs

0.25M SiC Mirror Polish Through CVD



Close up of Polish Through of CVD SiC

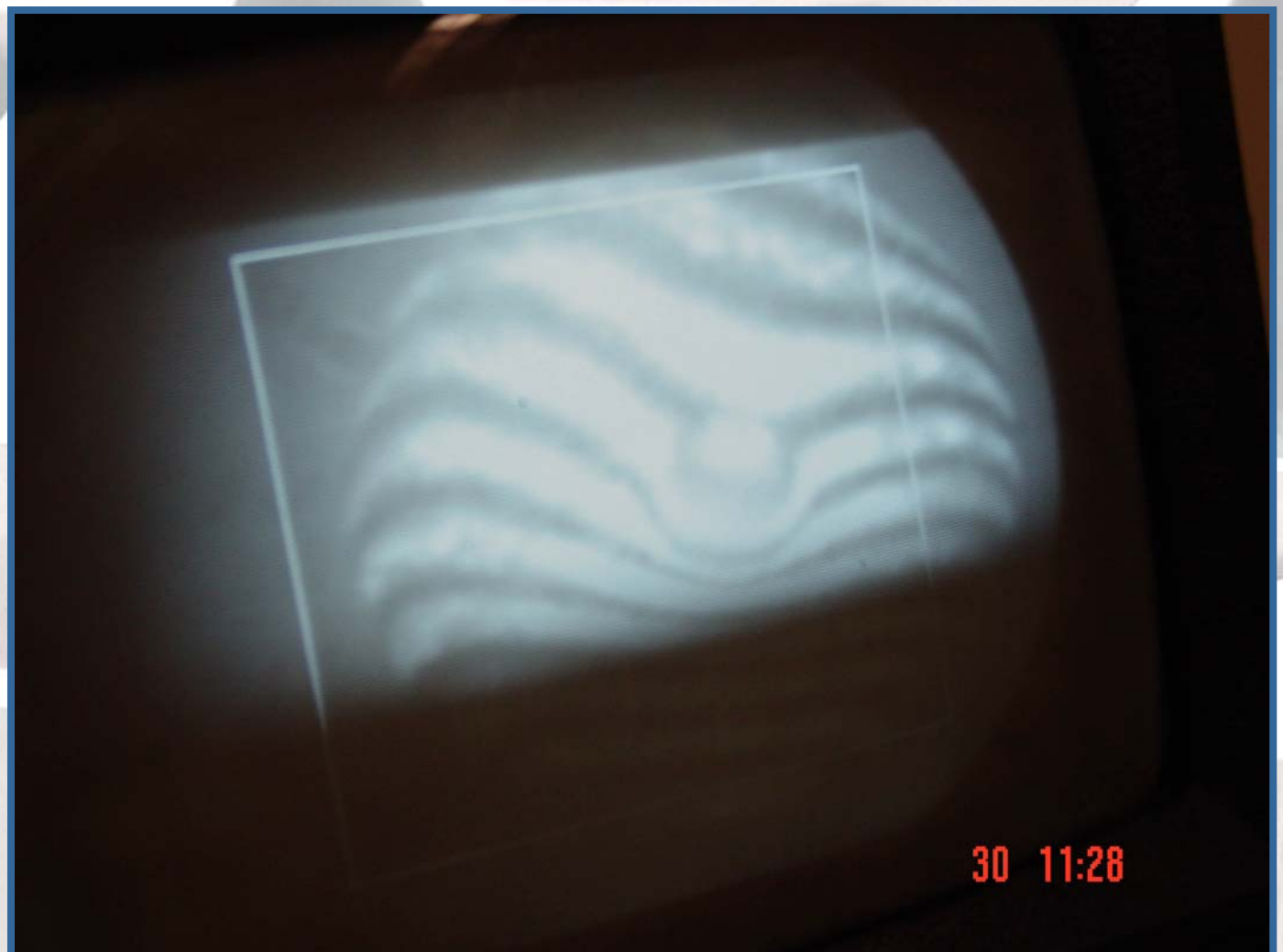
0.25 Meter Mirror on Mount



Close up of Polished Through of SiC

Ronchi Test of 0.25M SiC Mirror

Interferogram of 0.25M SiC Mirror



MSFC Lessons Learned

- The Poco SiC manufacturing process involves precision machining at every step of the mirror substrate fabrication. The very small tolerances of optical components require more extensive metrology than is typically used in standard components normally manufactured by Poco.
- Dimensional changes of 2-5 micrometers introduced by fixturing distortions during graphite machining or during conversion of the graphite to beta silicon carbide can significantly impact the thickness of the CVD coating that is required. These small dimensional changes must be monitored to allow corrective actions in grinding or CVD coating.
- Precision metrology can be preformed at every stage of mirror substrate manufacture beginning with graphite machining.
- Precision machining and metrology of reference surfaces is as important as the accuracy of the generated mirror contour.

MSFC Polishing Lessons Learned

- Efficient techniques for optical grinding and polishing silicon carbide require harder and stronger grinding and polishing materials than those used on materials that are not as strong and stiff as SiC.
- Grinding and polishing times are very acceptable when the proper technique and materials are applied.
- The thickness of the CVD SiC coating must be thick enough to allow the grinding and polishing process to produce the desire optical contour within the coating thickness. This means the coating thickness must allow for contour errors in the substrate and provide a margin for some extra polishing time on first article parts.